# Measuring Route Passenger Load Diversity for Capacity & Quality of Service Assessment

**Introduction**

- This poster introduces Passenger Relative Load Factor for a route or individual bus service as a capacity and quality of service measure, distinguishing it from Occupancy Load Factor
- It introduces Load Diversity Coefficient as the ratio of Passenger Relative Load Factor to Occupancy Load Factor, and relates Load Diversity Coefficient to Coefficient of Variation in Occupancy Load Factor
- It qualifies the operator's and passengers' perspectives of load factor based on Coefficient of Variation in Occupancy Load Factor along a route
- A case study using weekday Automatic Fare Collection (AFC) data on a premium bus line in Brisbane, Australia illustrates the methodology
- The compendium paper also qualifies the operator's and passengers' perspectives of these load factors along with Passengers' Average Travel Time for capacity and quality of service assessment

**Occupancy Load Factor of transit route *R* within Distance-Time Window *Z***

$$LF^{occ}{}_{R,Z} = \frac{\sum_{k=1}^{m}\left(\sum_{i=1}^{n}\left(t_{k,i}P_{OB,k,i}\right)\right)}{\sum_{k=1}^{m}\left(P_{MSL,k}\sum_{i=1}^{n}t_{k,i}\right)}$$

*The average load factor weighted by segment time along the route, from the operator's perspective.*

- Number of route segments, $n$
- Number of bus services, $m$
- Segment time, $t_{k,i}$
- Maximum schedule load of bus, $k$
- Passengers on board each segment, $P_{OB,k,i}$

**Passenger Relative Load Factor of transit route *R* within Distance-Time Window *Z***

$$LF^{pr}{}_{R,Z} = \frac{\sum_{k=1}^{m}\left(\frac{1}{P_{MSL,k}}\sum_{i=1}^{n}\left(t_{k,i}{P_{OB,k,i}}^{2}\right)\right)}{\sum_{k=1}^{m}\left(\sum_{i=1}^{n}P_{OB,k,i}t_{k,i}\right)}$$

*The average load factor weighted by segment time along the route, from the passengers' perspective.*

**Load Diversity Coefficient of transit route *R* within Distance-Time Window *Z***

$$LD_{R,Z} = \frac{LF^{pr}{}_{R,Z}}{LF^{occ}{}_{R,Z}}$$

*How much greater passengers experience average load factor along the route than the route's operator.*
*A normalized measure of evenness of passenger load, weighted by segment time along the route.*

**Coefficient of Variation in Occupancy Load Factor of transit route *R* within Distance-Time Window *Z***

$$LF^{occ}{}_{cv,R,Z} = \frac{1}{LF^{occ}{}_{R,Z}}\sqrt{\frac{\sum_{k=1}^{m}\left(\sum_{i=1}^{n}\left(t_{k,i}\left(\frac{P_{OB,k,i}}{P_{MSL,k}} - LF^{occ}{}_{R,Z}\right)^{2}\right)\right)}{\left(\left(\sum_{k=1}^{m}\left(\sum_{i=1}^{n}t_{k,i}\right)\right)-1\right)}}$$

*The coefficient of variation in load factor weighted by segment time along the route, from the operator's perspective.*

**Relationship between Load Diversity Coefficient and Coefficient of Variation in Occupancy Load Factor**

$$LD_{R,Z} = 1 + \frac{\left(LF^{occ}{}_{cv,R,Z}\right)^{2}}{\left(1 + \frac{1}{\left(\left(\sum_{k=1}^{m}\left(\sum_{i=1}^{n}t_{k,i}\right)\right)-1\right)}\right)} \approx 1 + \left(LF^{occ}{}_{cv,R,Z}\right)^{2}$$

*This relationship is relatively inelastic to the total online time within the denominator.*

**Acknowledgments**

- Academic Strategic Research Alliance (ASTRA), Queensland Australia
- Queensland Department of Transport and Main Roads (TransLink Division), Australia

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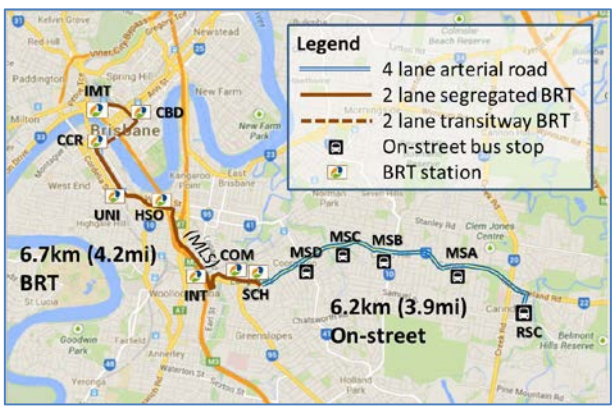
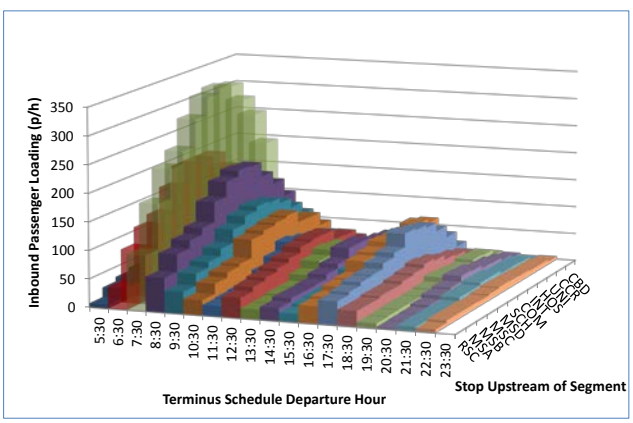
| Coefficient of Variation in Occupancy Load Factor along Route | Operator's Perspective of Loading Diversity along Route | Passengers' Perspective of Average Load Factor Relative to Operator's |
|---|---|---|
| 0 | • Point to point route or<br>• Exact balance/s between boardings, alightings at all stops<br>• Optimal loading pattern | • Same as operator |
| Up to 0.2 | • Extremely even balance/s between boardings, alightings at all stops<br>• Extremely productive loading pattern | • Up to 4% higher than operator |
| Up to 0.4 | • Very even balance/s between boardings, alightings at all stops<br>• Very productive loading pattern | • Up to 16% higher than operator |
| Up to 0.6 | • Good balance/s between boardings, alightings at all stops<br>• Productive loading pattern | • Up to 36% higher than operator |
| Up to 0.8 | • Fair to poor balance/s between boardings, alightings at all stops<br>• Unproductive to very unproductive loading pattern | • Up to 64% higher than operator |
| Up to 1.0 | • Very poor balance/s between boardings, alightings at all stops<br>• Highly unproductive loading pattern | • Up to twice as high as route occupancy load factor |

**Case Study Application: Premium Bus Route 222 Inbound, Brisbane Australia**

- 5 on-street segments, 7 Bus Rapid Transit segments
- 15min off-peak frequency between 05:00 and 23:30, 10min frequency during morning peak two hours
- Fleet consisted of 12.5m (41.0ft) buses with 45 seats ($LF = 0.69$) and 65p maximum schedule load ($LF = 1$)
- Automatic Fare Collection boarding and alighting data obtained for a normal 2012 weekday
- Strong morning peak and softer evening counter-peak



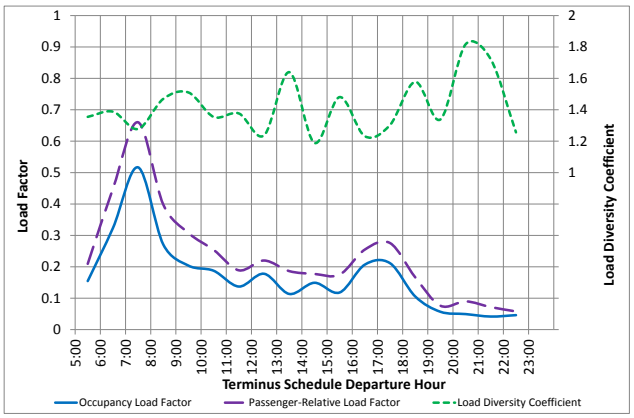
# TRB 95th Annual Meeting Session 659 Paper 16-0052

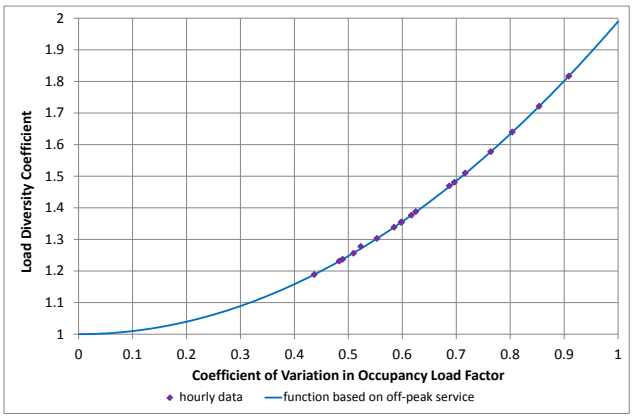
**Load Factors and Load Diversity by Hour**

- The peak value shows us that Passenger Relative Load Factor tells us more about quality of service.
- Still, Load Diversity is lowest during peak periods when passengers make longer commute trips.
- Load Diversity is greatest during low demand periods, when shorter journeys are made.

**Load Diversity vs CV in Occupancy Load Factor**

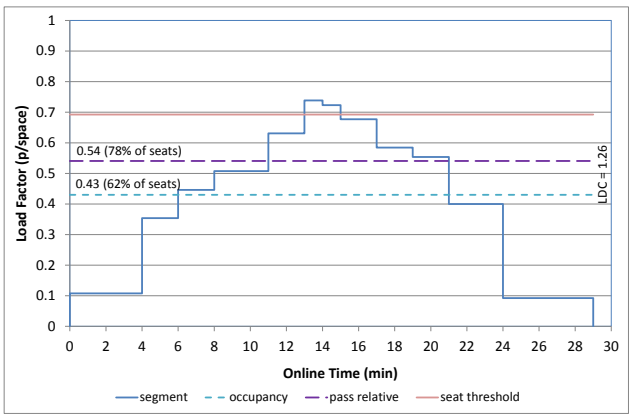
- CV in Occupancy Load Factor is a traditional statistical measure of how load varies between segments in time, along the route.
- Load Diversity Coefficient provides more insight into differences between passenger and operator perspectives, for quality of service assessment.

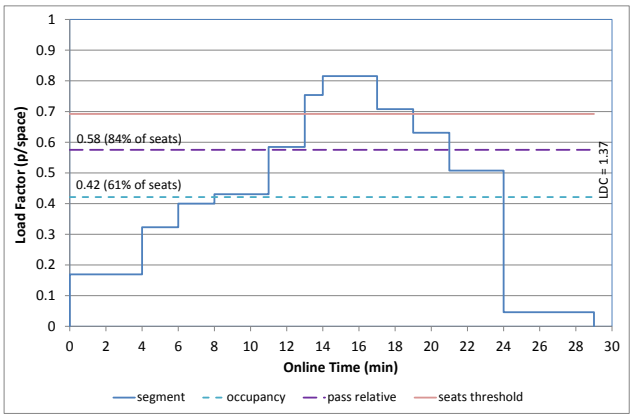



**Comparison between 06:55 and 08:35 shoulder peak period inbound bus services**

- From the operator's perspective, Occupancy Load Factor and therefore use of available passenger time-spaces, is practically equal between both buses.
- However, Passenger Relative Load Factor is 6 percent higher on the 08:35 bus. The average passenger on the 8:35 bus perceives that almost an extra row of seats is taken than one on the 06:55 bus.
- Using the *single measure* of Load Diversity Coefficient, we can understand that the 06:55 bus has a more productive loading pattern, and better balance of boardings and alightings between stops.




**Advantages of Methodology**

- Requires only AFC and schedule data.
- Can be used to identify operational concerns along a route in time and space, and as a schedule improvement analysis tool.

**Future Research**

- Pursue transit route analysis across a number of consecutive study days and compare different routes.